InGaP/GaAs DHBTs with Composite Collectors for Power Amplifiers

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Heterojunction bipolar Transistors (HBTs) have shown promise in the field of microwave power applications. Recently InGaP/GaAs HBTs have been considered an alternative to AlGaAs/GaAs HBTs. The use of widegap collectors in InGaP/GaAs high-power microwave HBTs can increase the breakdown voltage and reduce offset voltage thus improving their power handling capacity and efficiency. This works focuses on a new InGaP/GaAs DHBT with collector combined of InGaP and GaAs for application to power amplifiers. InGaP/GaAs DHBTs with composite collectors have been simulated, fabricated, and characterized. This new DHBT improves the characteristics of a conventional DHBT in knee-voltage (on-resistance), cutoff frequency (f_T), and power efficiency.

A 200 Å of undoped GaAs and a 200 Å n-type ($5x10^{17}$ cm^{-3}) doping of InGaP were utilized to reduce the conduction band barrier effectively at base-collector junction. The main parameter investigated here for device simulation is the thickness (d) of GaAs in a 4000 Å collector. Where d = 0 Å stands for the conventional DHBT and d = 4000 Å for the conventional HBT (with the omitting of the 200 Å n-type doping of InGaP). The simulated Gummel plots for the proposed InGaP/GaAs DHBTs showed the negligible difference in current gains due to the identical structures in base-emitter regions. The simulated *rf* performance demonstrated that HBT (d = 4000 Å) has the highest f_T compared to other DHBTs due to the higher electron saturation velocity in GaAs than that in InGaP. On the other hand, if the thickness of GaAs in the collector is thicker than 3000 Å, the corresponding breakdown voltage (BV_{CBO}) decreases. The tradeoff between BV_{CBO} and f_T will be depended on the device application. In addition to the consideration of f_T and breakdown voltage, on-resistance and offset voltage are also simulated. The on-resistance is improved in DHBTs by decreasing the thickness of InGaP in the collector. The reduced on-resistance in the new InGaP/GaAs DHBT can improve the power added efficiency for power amplifier application.

Finally, InGaP/GaAs HBTs with different structures in collectors have been grown, fabricated and characterized. There are InGaP/GaAs HBTs, InGaP/GaAs DHBTs, and InGaP/GaAs DHBTs with composite collector. The composite collector is a combination of 3000 Å InGaP and 3500 Å GaAs. The measured results showed the following results: 1) negligible difference in current gains; 2) better on-resistance in InGaP/GaAs DHBT with composite collector than that in InGaP/GaAs DHBT; 3) better offset voltage in InGaP/GaAs DHBT with composite collector than that in InGaP/GaAs HBT. Power transistors with emitter size of 4x12x20 μm^2 biased at Class-A have also been measured to evaluate the output power and efficiency.

	Type	New DHBT	Thickness (A)	Doping (cm^{-3})
Cap Layer	n	InGaAs	400	1x10^{19}
	n	InGaAs	400	1x10^{19}
	n	InGaP	300	5x10^{18}
Emitter	n	InGaP	600	4x10^{17}
Base	p	GaAs	800	4x10^{19}
	undoped	GaAs	200	undoped
	n	InGaP	200	5x10^{17}
Collector	n	InGaP	4000-*d*	3x10^{16}
Collector	n	GaAs	*d*	3x10^{16}
	n	GaAs	4000	5x10^{18}
S.I. GaAs Substrate				

Fig. 1 Epitaxial structure of the proposed InGaP/GaAs DHBTs.

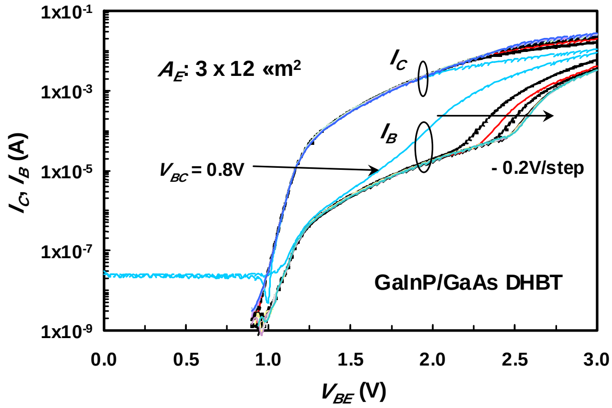

Fig. 2 Measured Gummel plot of InGaP/GaAs DHBTs with different V_{BC} showing no conduction barrier at base-collector junction.

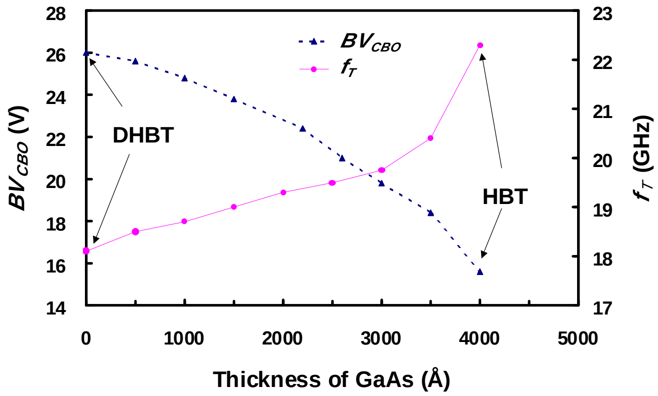

Fig. 3 Calculated BV_{CBO} and f_T of InGaP/GaAs DHBTs with different thickness of GaAs in collector.

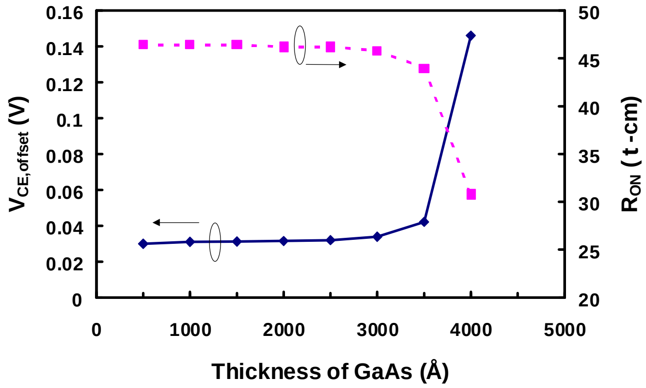

Fig. 4 Calculated $V_{CE,offset}$ and R_{ON} of InGaP/GaAs DHBTs with different thickness of GaAs in collector.

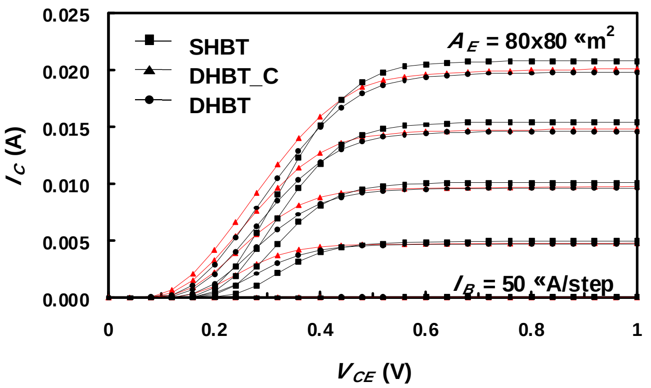

Fig. 5 Measured *I-V* characteristics of three different InGaP/GaAs (D)HBTs.

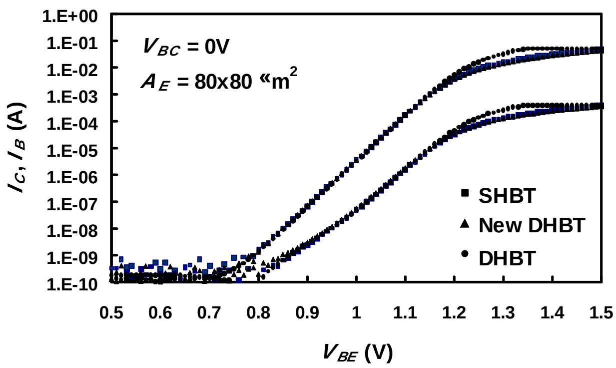

Fig. 6 Measured I_C and I_B of three different InGaP/GaAs (D)HBTs

	SHBT	New DHBT	DHBT
R_{ON} (Ω)	17.5	20.5	24.6
$R_B + R_C$ (Ω)	12.1	15.2	19.5
$V_{CE,offset}$ (V)	0.16	0.12	0.12
β	101	105	110
BV_{CBO} (V)	14	28	31

Table 1 Measured R_{ON}, $V_{CE,offset}$, $V_{CE,offset}$ and BV_{CBO} of three different InGaP/GaAs (D)HBTs

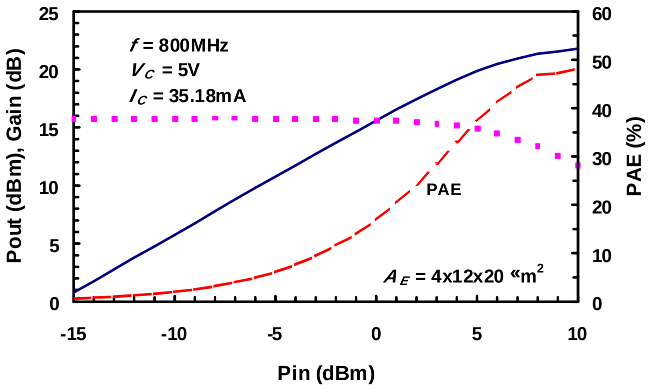

Fig. 7 Measured output power and efficiency vs. input power for InGaP/GaAs DHBT with composite collector.